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Bushey,
C.L.

Integrating Forest Service Timber Management and Land Management Planning

FINAL REPORT FOR COOPERATIVE AGREEMENT
No. 22-C-4-INT-033
WITH SYSTEMS FOR ENVIRONMNTAL MANAGEMENT
Co-op Contact Charles L. Bushey
FS Contact: J.K. Brown

In TWO PARTS

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Final Report for Cooperative Agreement
#22-C4-INT-033
with Systems for Environmental Managemer
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Methods for Monitoring and Evaluation Bureau of Land Management Resource Objectives.

Charles L. Bushey

Systems for Environmental Management

A final report submitted to partially fulfill the requirements of Cooperative Agreement 22-C-4-INT-33.

September 30, 1987

SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

P.O. BOX 8868
MISSOULA, MONTANA 59807
PHONE: (406) 549-7478

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→ C. Elwood

United States Department of Agriculture

Forest Service

INT - IFSL

Reply to: 4040 Cooperatives

Date: November 13, 1987

Subject: Final Report - 22-C-4-INT-033

To: Director, INT
THRU: Richard G. Krebill, ASD-Research

B&RA
BRA
WESTFORNET
IN TURN

RK

Enclosed are two reports dealing with (1) three-year post burn response in the sagebrush/grass ecosystem and (2) methods for monitoring and evaluating prescribed fires. These are the final reports for the Cooperative Agreement with Systems for Environmental Management involving a prescribed fire demonstration study on BLM lands in four western states (22-C-4-INT-33). All obligations of this Coop Agreement have been met and it should be officially terminated.

James K. Brown

JAMES K. BROWN
Project Leader
RWU 4403

Enclosure

See also:

SHORT-TERM VEGETATION RESPONSE TO PRESCRIBED BURNING IN THE SAGEBRUSH/GRASS ECOSYSTEM OF THE NORTHERN GRAET BASIN; THREE YEARS OF POSTBURN DATA FROM THE DEMINSTRATION OF PRESCRIBED ON SELECTED BUREAU OF LAND MANAGEMENT DISTRICTS

SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

A Natural Resources Research Group

Systems for Environmental Management (SEM) is a non-profit research and educational corporation based in Missoula, Montana, a regional center for natural resources agencies. Founded in 1977, SEM works cooperatively and under contract with the U.S. Forest Service, National Park Service, Bureau of Land Management, and Bureau of Indian Affairs, as well as state and academic institutions, private individuals and organizations.

SEM's diverse professional staff offers a wide range of research capabilities within the natural resources management field. The full-time staff includes specialists in fire behavior, fire history, recreation management, geography, plant ecology, forestry, meteorology, data analysis, and computer science. SEM also maintains a pool of professional affiliates that can be utilized for projects requiring additional expertise. Areas of recent research emphasis include wilderness recreation management, fire history and ecology, fire planning, and development of computerized resource management tools.

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1. Planning.

1.1 Data Collection Requirements.

For a land manager to evaluate changes in resource values it is necessary to periodically establish either a quantitative or qualitative check of those values. The process of using various measurement methods to establish levels of resource value is commonly termed monitoring. Specific area or numerical units of the measurements are considered individual samples of the monitoring process. Assessing the level of change over time in the compiled samples provides an index for the manager to evaluate accomplishments or damage from a management activity. Data required for monitoring accomplishments of treated resources needs to be consistent with identified needs or resource objectives on the land unit being evaluated. Objectives listed in land-use plans are established by the coordinated efforts of the resource management team and finalized by the authorized officer. Resource objectives from the land-use, coordinated resource management, and management activity plans are used to establish a framework and criteria for determining the levels of intensity and reliability desired for monitoring. Land units which have significant resource conflicts, controversy, potential for improvement, scientific or cultural features, or managed with a treatment activity that yields inconsistent or unknown results may require more intensive monitoring. Established monitoring programs need to be flexible enough to respond to new issues of concern should they arise. This increased flexibility may involve additional sampling at a higher intensity level than originally intended.

2. Coordination.

Treatment monitoring programs and baseline inventory data collection should be coordinated to provide for the most efficient collection of the data needed to ensure the greatest use of the data. Where baseline inventories have been completed, existing data may provide the starting point for monitoring. Where baseline inventories are scheduled, data collection should be planned to complement either current monitoring data or what may be needed once monitoring is initiated. When a principal investigator of a monitoring program moves on to other responsibilities that investigator should be throughly debriefed concerning the status of monitoring programs. Equally important, new investigators need to be informed of site monitoring techniques and schedules and other incumbent monitoring responsibilities.

2.1 Interdisciplinary Coordination. Monitoring programs should be coordinated closely to ensure all facets of multiple-use management are considered. This prevents duplication of effort and ensures a free flow of information among resource programs. Coordinated monitoring plans provide for intergrated data collection necessary to assess the effectiveness of on-the-ground management actions and to determine progress in resolving resource problems and conflicts and meeting management objectives. If specific monitoring studies are needed for program management they should be established by the programs.

2.2 Inter-Area/District/State Coordination. Ongoing and future monitoring programs should be coordinated with adjoining areas, districts, and states. This coordination should address the similarities and differences between the programs with regard to study methods, training, studies schedules, data storage and assess, consultation, cooperation, coordination with rangeland users and other interested parties, and the evaluation format and schedule. Coordination facilitates the sharing and evaluation of data related to a resource management action and minimizes misunderstanding among affected and interested parties. Coordination also aids the exchange of data for regional BLM planning activities.

3. Priority.

The BLM cannot intensively monitor the effectiveness of on-the-ground management actions on all the range and timberlands it administers because of funding and personnel constraints. Therefore, priorities concerning monitoring needs should be assigned by allotment, wildlife habitat area, herd management area, watershed area, or other designed management area. Following is a list of criteria that can be used, as appropriate, in assigning priorities.

1. Land-use plan objectives (such as the three categories of allotments - maintain, improve, and custodial).
2. Coordinated resource management plan objectives.
3. Activity plan objectives.
4. Intensity of planned management efforts.
5. Current productivity.
6. Current resource values.
7. Current ecological status.
8. Resource conflicts/controversy (known and anticipated).
9. Significance of unresolved issues.
10. Present and future management.
11. Known or anticipated changes in grazing management.
12. Potential for improvement.
13. Potential for economic return on investment.
14. Socio-economic situations.
15. Special/unique situations (example: crucial habitat).
16. Threatened, endangered, or sensitive species habitat.

17. Status of range improvement (lacking, adequacy, maintenance).

4. Monitoring Design.

4.1 Resource Management Objectives. Sampling of vegetation to monitor change on the landscape requires different techniques for different resource management objectives, vegetation types, and levels of sampling intensity. Sampling should be appropriate to the identified need based on established objectives for the land unit. Following is a list of generalized resource management objectives that are frequently identified in BLM planning documents, and environmental assessments. These resource objectives usually require some form of disturbance to vegetation, which may require monitoring and the approximate percent success identified over a specified period of time.

1. Site preparation.
2. Timber stand improvement.
3. Vegetation conversion.
4. Woodland/timber product debris removal.
5. Hazard reduction.
6. Insect and disease control.
7. Improve quality or increase quantity of grass.
8. Improve quality or increase quantity of forbs.
9. Improve quality or increase quantity of shrubs.
10. Improve quality or increase quantity of trees.
11. Reduce competition from undesirable plant species.
12. Maintain desired range condition.
13. Increase utilization by grazing/browsing animals.
14. Create openings for travel, dusting, feeding or use.
15. Increase edge effect.
16. Improve streambank condition.
17. Increase watershed storage capacity.
18. Reduce consumption of water by undesirable plant species.
19. Maintain fuel breaks.
20. Improve esthetics.

21. Improve recreational access and use.

22. Restore and maintain natural role of fire.

23. Improve boundary lines around previously disturbed sites.

4.2 Design considerations. The appropriate measurement methods to monitor for objective attainment will depend on the complexity of the land units resource objectives; the sensitivity of known or anticipated resource use conflicts or controversy; anticipation of the level of on-the-ground management activities; the diversity and variability of vegetation types and their current ecological status and trend; and the desired level of statistical precision. Sample intensity (number or size of samples) and the type of measurement method is dependent on the kind, quality, and quantity of data needed at each site. The stratification, key area, and key species concepts can be used, as appropriate, in selecting study sites where data will be collected. These concepts are discussed in detail in USDI Technical Reference 4400-1 (1984), Section 5.11 through 5.13. Basic sample measurement methodologies are described in USDI Technical References 4400-2 (1984), -3 (1984), and -4 (1985). These techniques, and others that are appropriate, are presented and their limitations discussed for the generalized resource objectives listed previously. When selecting a methodology of measurement and sampling design for monitoring, the following factors will also need to be considered at the earliest planning stages.

(a) Use of several short transects may be more advantageous than one long transect and will be easier to establish within a homogeneous, or stratified unit.

(b) For most statistical tests to be valid randomization must be initiated in the sampling design. Randomization allows for an unbiased estimate of error and permits establishment of confidence limits. A disadvantage of random sampling is that large areas of the landscape, and important information may be missed without an impractical sample size. A systematic location of transects (sample lines) and/or plots (individual samples with defined area boundaries) violates randomization, but allows a subjectivity that can provide a more precise and accurate concept of the resource being monitored. Systematic sampling is commonly utilized in gradient analysis where a known environmental gradient is identifiable, or within specified vegetation units delineated as homogeneous and statistics are still used thought he concept of randomness is violated and bias introduced into the sampling process. If statistical interpretation is not necessary, or can be utilized with minimal concern for randomness, systematic sampling may be preferred as an efficient alternative. A compromise between the random and systematic designs is the stratified random design which allows a large area to be broken into uniform sized grids in which samples (selected from a random number table) are established within the axes of the grid.

(c) Every effort should be made to minimize bias (systematic distortion) of plot establishment within a land unit, and to increase

accuracy and precision of the sample being collected. Accuracy can be improved by identification of the sampling needs and design the methodology to address those needs (reduction of internal variation). Precision can be increased by increasing the sample size. When long-term monitoring (greater than one sample period) is necessary from permanently marked transects or plots, additional factors must be considered to maintain accuracy and precision. Transects and plots must be clearly identified and marked for relocation. Individuals responsible for data collection preferably should be the same or at least have a similar understanding of the methodology, species identification, and appropriate sampling rules and definitions. Sampling may also need to be conducted at a specific phenological period, or repeated at specified intervals during differing phenological periods.

(d) To evaluate treatment effects it is necessary for the investigator to either eliminate or account for the influence of outside factors other than the treatment. To accomplish this it is necessary to establish control transects measuring the same resource parameters as are measured on the treatment transect. The control transect should be located in as nearly identical vegetation and site conditions to the treatment transect as possible. The control should remain free of factors which will affect plant mortality and growth to reflect the untreated vegetational condition. Comparison of the data from the companion treatment/control transects should be accomplished after each sampling period.

5. Determining Sample Size.

The number of samples needed to adequately measure an area depends on the characteristics of the vegetation and the degree of precision required. Determination of adequate sampling relies on the knowledge and experience of the investigator. Several methods are available to aid in determination of adequate sample size.

5.1 Species-Area Curves. The number of species (vertical axis) found in the samples are plotted against the sample size (horizontal axis) which may be expressed as either cumulative area or the number of samples. The curve plotted will rise rapidly at first because of the number of new species located during the sampling process. With increasing numbers of samples or area size sampled the number of new species diminishes (Vestal 1949). At a predetermined arbitrary level of increase in the number of species or increase in size (10% is a commonly used level) plot sampling can cease. This method works well as a qualitative floristic technique because it only uses the number of species and will not express other factors such as basal area, density, etc.

5.2 Standard Error of Mean/Mean Curve. This technique is similar to the species-area curve and has the same relationship of diminishing returns with increasing sample size. The curve should be considered only as a guide and applies to only species or groups which occur with a random distribution. The standard error of the mean/mean ($\frac{1}{\sqrt{x}}$) is plotted on the vertical axis and the number of individuals along the

horizontal axis (Mueller-Dombois and Ellenberg 1974). If a random distribution can not be assumed calculate the standard error of the mean (SEM) as the square root of the variance (S^2) divided by the number of samples (n).

$$SEM = \sqrt{\frac{S^2}{n}}$$

5.3 Running Mean Curve. Plotting the running mean ($\bar{x}/n$) can be used to determine adequate sample size. The running mean values are plotted on the vertical axis, the number of samples on the horizontal axis. Sampling is stopped at an acceptable level of reduced variation (Mueller-Dombois and Ellenberg 1974).

5.4 Coefficient of Variation. The coefficient of variation ($C = S/\bar{x}$) can be used as a guide for determining the level at which additional information is unlikely to be gained. The variance (C) is plotted against the number of samples or area of the samples. The first few samples will be erratic, with increasing samples the variance stabilizes and additional sampling may be determined unnecessary.

6. Measurement Methods.

6.1 Plant Quantity Ranking. Quantity ranks are a relatively rapid method of either qualitatively or semi-quantitatively evaluating a component, or series of components within an ecosystem. Because these are low intensity methods a limited amount of information is made available to the investigator.

a. Abundance Ranks. Abundance is a term which expresses a numbering system to qualitatively state species or object quantities within a specified area. Estimates of abundance are usually expressed in broad class ranks such as rare, occasional, frequent, abundant, and dominant. These classes of quantities are satisfactory for many purposes of floristic vegetation description, but are vague and subjective for treatment evaluations. Better measures of abundance can be obtained from actual counts on sampled units.

$$\text{Abundance} = \frac{\text{number of individuals of species A}}{\text{number of sample occurrences}}$$

These counts are usually time consuming and are not often used. Even if the count method is not used, the evaluation of a series of sampled units in either plot or transect format allows for better preparation of an accurate estimate. These smaller units of landscape need to be of a size and orientation which are easily viewed by the investigator. Because abundance measures are not fixed to a final area size they will vary with the species sampled. Without a fixed final size, abundance is not nearly as meaningful as other measures. The concept of evaluating units of landscape and placing the components into a more meaningful, semi-quantitative system of ranks was pioneered by Braun-Blanquet (1932)

and termed "species magnitude". This system combined information from cover and abundance into a numerical class rank.

b. Coverage Ranks. Daubenmire (1959, 1968) adapted the seven class Braun-Blaquet (1932) cover estimate rank to develop the six class "Daubenmire Cover Scale" (see USDI 1985, TR 4400-4, Section 4.43) which expresses the quantity of vegetative coverage. A ten class "Daubenmire Coverage Scale" was developed to provide better estimates of species with higher cover values. Vegetation height can be a critical factor in the use of a coverage rank. Daubenmire (1959) states that the coverage estimation technique "becomes awkward as plants begin to exceed waist height". Oblique views will provide misleading estimates with items of lessor height obscured and the merging of taller items. This effect increases with increasing viewing angle or distance from the landscape being estimated.

6.11 Potential Objectives Which May Be Monitored Using Quantity Ranks. General resource objectives which could use quantity ranking as part of a treatment monitoring program include the following categories.

1. Vegetation conversion.

2. Reduce competition from undesirable plant species.

3. Improve streambank condition.

4. Reduce consumption of water by undesirable plant species.

5. Improve esthetics.

6. Improve recreational access and use.

6.12 Advantages and Disadvantages of the Ranking Methods. Scale measures of quantity, and in particular the "Daubenmire Cover Scale" have several advantages which have facilitated use of these techniques.

a. Comprehension. The methods and concepts are relatively simple to understand and can usually be measured rapidly.

b. Training level. With a minimal amount of training different investigators can provide reproducible results.

c. Sample size. Reasonable estimates can be obtained with a smaller surface area than is necessary with other techniques, only 40 to 50 samples.

d. Supplementary data. Ground surface data can be easily collected at the same time, and more than one lifeform can be evaluated.

e. Analysis. Calculations are simple compared to other analytical methods.

f. Climatic influences. Large changes in herbaceous and woody vegetation quantity ranking, especially coverage, can be induced by

climatic influences. These fluctuations can introduce considerable variation into periodic remeasurements. The variations accurately reflect the factor being measured but can also mask the effects of, or be totally unrelated to, a prescribed treatment or other management activity.

g. Assigned ranks. Ranking systems force the investigator to assign a difference even though little or none can be detected. The quantitative differences in these observations with adjacent ranks is ignored causing a loss of information and efficiency. Quantity ranks need to be combined with other analytical techniques to better evaluate treatments which may result in abrupt changes in vegetative structure and composition.

6.13 Examples of Different Scales of Estimating Species Quantities.

a. Braun-Blanquet Cover/Abundance Scale.

Class	Abundance	Range of Cover
r	solitary	cover small
+	few	cover small
1	plentiful	cover up to 1/20 of sample unit (5%)
2	any number	cover from 1/20 - 1/4 (5 - 25%)
3	any number	cover from 1/4 - 1/2 (25 - 50%)
4	any number	cover from 1/2 - 3/4 (50 - 75%)
5	any number	cover more than 3/4's (75%)

b. Daubenmire Cover Scale - Six Classes.

Class	Range of Cover	Class Midpoint
1	0 - 5%	2.5%
2	5 - 25%	15.0%
3	25 - 50%	37.5%
4	50 - 75%	62.5%
5	75 - 95%	85.0%
6	95 - 100%	97.5%

c. Daubenmire Cover Scale - Ten Classes.

Class	Range of Cover	Class Midpoint
1	0 - 5%	2.5%
2	5 - 12.5%	8.75%
3	12.5 - 25%	18.75%
4	25 - 37.5%	31.25%
5	37.5 - 50%	43.75%
6	50 - 62.5%	56.25%
7	62.5 - 75%	68.75%
8	75 - 87.5%	81.25%
9	87.5 - 95%	91.25%
10	95 - 100%	97.5%

d. Bailey and Poulton Cover Scale (1968).

Class	Range of Cover	Class Midpoint
1	0 - 1%	.5%
2	1 - 5%	3.0%
3	5 - 25%	15.0%
4	25 - 50%	37.5%
5	50 - 75%	62.5%
6	75 - 95%	85.0%
7	95 - 100%	97.5%

6.2 Plant Occurrence/Composition. A floristic listing or survey of the plants which occur within an area will provide an index of the species present. Changing an areas species composition is frequently a treatment objective. If the objective is the elimination of selected species, or the introduction of species not previously observed, then a floristic list may be a satisfactory, qualitative, low-intensity monitoring method. Sufficient compositional data can usually be obtained with the collection of other data sets with more intensive methods, such frequency, density or dominance measurements.

6.21 Potential Objectives Which May Be Monitored Using Occurrence/Composition Data. General resource objectives which could use plant occurrence or composition data as part of a treatment monitoring program include the following categories.

1. Vegetation conversion.

2. Reduce competition from undesirable plant species.

3. Improve esthetics.

4. Restore and maintain natural role of fire.

6.22 Advantages and Disadvantages of Occurrence/Composition Determination. The concept of species occurrence is not complicated by efforts to determine number, size, dispersion, and species vigor.

a. Training. Occurrence data can be rapidly acquired by an experienced investigator with knowledge of plant identification. If different investigators are conducting the surveys it will be especially important that they use the same taxonomic nomenclature.

b. Analysis. Data sets can be utilized with little or no analysis. The data may also be restricted to a particular life form, stratum level, or other arbitrary classification system. Problems can arise if species of concern are infrequent or rare, and difficult to locate. The investigator needs to take into account species which may not have had prior visible evidence of their presence but were released by a treatment from a soil seedbank and delineate these from possible species missed in earlier surveys. Also the presence of annual and biennial species flucutate considerably and may or may not provide useful information.

c. Supplementary Data. Occurrence/absence lists do not provide meaningful information about underlying community relationships. To obtain community relationship data more time consuming methodologies must be employed.

6.23 Analytical Methods Using Occurrence/Composition Data.

a. Presence. This method is a measurement of distribution among multiple stands or sites. Stands evaluated by this method are arbitrarily limited to units of similar vegetation of varying shape and size. Analysis of presence can provide an index of species change over time. Data analysis is accomplished on a species or "classification of interest" level. The number of stands with a species occurrence are divided by the total number of stands investigated and provides a percentage of presence.

$$\text{Presence} = \frac{\text{number of stands with species A}}{\text{total number of stands}} \times 100$$

Braun-Blanquet (1932) present an arbitrary classification system which is satisfactory for summary purposes.

I. 1 - 20%, rare
II. 20.1 - 40%, seldom present
III. 40.1 - 60%, often present
IV. 60.1 - 80%, mostly present
V. 80.1 - 100%, constantly present

b. Constancy. To determine absolute constancy it is necessary to have samples within multiple stands or sites being investigated. The shape and size of the samples need to be consistent from stand to stand though the number of samples per stand can vary. The previous method, presence, did not need to have established samples. Absolute constancy refers to the number of samples in which a particular species occurs, and can be analyzed by either individual stand or by total sample area. If evaluation is by total sample area then the number of occurrences are divided by the number of stands. Absolute constancy can be converted to a percentage and used as relative constancy.

$$\text{Relative Constancy} = \frac{\text{number of samples with species A}}{100}$$

6.3 Plant Frequency. Frequency expresses the degree of occurrence or abundance (concepts of species distribution and composition) with which a species or object may be encountered within a sampling unit. This measurement is expressed as a percentage of the total number of samples units (plots) in which the specimen being recorded occurred.

$$\text{Frequency} = \frac{\text{number of samples with species A}}{\text{total number of samples}} \times 100$$

Frequency is a nonabsolute measure dependent upon the size and shape of the sample frame. This measure can be made absolute if the sample is reduced to a point. Do not relativize frequency measurements, frequency is already expressed as a percentage. Vegetation monitoring of a prescribed treatment using frequency as the only analytical measure may not provide the needed data base for analysis of prescribed treatment effects. Usually frequency data is collected in combination with another analytical measure for a more detailed evaluation of community structure. Two types of frequency measurements can be collected.

(a) Rooted frequency. Only the individual plants rooted in a sample are counted, this is the method most commonly used.

(b) Shoot frequency. All shoots that fall within a sample area are counted.

6.31 Potential Objectives Which May Be Monitored Using Frequency. Examples of general resource objectives which could use plant frequency determination as part of a treatment monitoring program include the following categories.

1. Vegetation conversion.
2. Insect and disease control.
3. Reduce competion from undesirable plant species.
4. Maintain desired range condition.
5. Improve streambank condition.
6. Increase watershed storage capacity.
7. Reduce consumption of water by undesirable plant species.
8. Improve esthetics.

6.32 Advantages and Disadvantages of Frequency Determination. Frequency has the advantage of being simple to collect, and if collected properly provides relatively stable measurements for perennial plants and non-transient objects from year to year (Hyder and others 1966, Mueller-Dombois and Ellenberg 1974). Several factors can influence the results obtained when frequency data is collected.

a. Plot size. Large plots will express higher frequencies than smaller plots which might miss species or objects being sampled. Large enough plots would result in the more abundant species having frequencies of 100%. It has been suggested that a plot size which

samples the sites most abundant species at a frequency of 63 - 86% is proper (Curtis and McIntosh 1950, Smith 1982). Winward and Martinez (1983) gave a sample frequency range of 20 - 80% for species in the community as ideal. With high densities larger plot size will increase frequency to a point. With low densities the frequency will increase slowly so an increase in plot size will not make much of a difference (Curtis and McIntosh 1950).

b. Plot shape and location. Plot shape will influence the "edge effect" and the surface area of the sampling plane. The greater the amount of edge the more frequent will be a sampled object that lies on the edge. Objects on the edge of a plot require a subjective decision of whether the object is in-or-out of the plot. A circular plot shape has the least amount of edge. Circles when placed on slopes greater than 20% will need to be corrected for horizontal surface area. Horizontal surface area in a circular plot increases with increasing slope. Rectangular plots placed perpendicular to the slope minimize the influence of slope on the plot surface area, but have a greater edge effect than circular plots. Square plots have the greatest amount of edge and are intermediate of the three shapes in terms of the influence of slope on surface area. To great of an elongated rectangular plot increases in edge effect with results similar to small square plots (Greig-Smith 1964). Each shape is a compromise of the ideal situation, circles are best on level sites where the amount of edge is critical, rectangles are preferred on sites with greater than 20% slope.

c. Sample size and plant distribution. Too few plots will under represent, or miss entirely the least common species or objects being sampled. Enough plots need to be sampled so nearly all species present are recorded. Mosley and others (1986) determined that within dry mountain meadows the most common species of herbaceous vegetation were adequately sampled ($o = .20 \pm 10\%$) with one hundred plots. Smith and others (1986) have shown that a minimum of 100 plots are necessary. Sensitivity increased significantly up to approximately 200 plots per site with only minor increases in sensitivity thereafter. Different plant communities may require more or less plots (see Determining Sample Size, Section 5). Consideration of the fact that most plants species are not randomly distributed may also influence the number of samples. Plants commonly grow in clumped or patchy patterns and if sampled by frequency alone these plants may have a low frequency measurement while actually having a very high density. The same number of plants spread out over a larger area may result in a higher frequency value. Because of this artifact, it is often better to combine frequency with another analytical measurement to obtain a better information base.

d. Plant size. Single stemmed, large plants may have a low frequency due to their space requirements. These large growth forms may physically dominant a site and its resource allocation compared to smaller but more frequent forms. Frequency may not truely represent a species overall importance to the community or ecosystem being evaluated.

e. Plant growth patterns. Sod-forming grasses and other plants with extensive tillering root systems, or multistemmed growth forms create

problems in defining what constitutes a species presence or absence. Plants that have greater than 50% of their basal area within a plot are generally accepted as being recorded. Plants such as sod-forming grasses are accepted as a rooted tiller, and plants with surface runners up to three inches in length and bearing functional rootlets are counted as individuals (Brown 1954).

6.33 Relationship to Other Analytical Measures. Because frequency is a nonabsolute measure that is dependent on the number of samples and plot size it is difficult to directly compare with other analytical measures. If frequency is determined, and the species distribution is known to be random (rarely occurs), then density can be determined. This can save time in counting of large numbers of herbaceous stems. The following equations express this relationship.

$$\text{Density} = -\log_e (1 - F/100)$$

$$\text{Frequency} = 100 (1 - e^{-D})$$

Mean area per species is the reciprocal of density. With a known random distribution the mean area per species can be calculated (Curtis and McIntosh 1950). Frequency gives very little or no indication of coverage (Mueller-Dombois and Ellenberg 1974) or yield.

6.34 Comparison of Different Methodologies of Obtaining Frequency.

a. Pace Frequency Method (see USDI 1985, TR 4400-4, Section 4.44). Rapid data collection, but limited analysis and interpretative capability is possible because of the lack of permanent data collection points. Problems created by the lack of established plot locations can be overcome to a limited extent with increased intensity of sampling.

b. Quadrat Frequency Method (see USDI 1985, TR 4400-4, Section 4.45). Takes longer to initially read the plots because of the need to precisely establish the transect and plot location for future readings. Once established the transects are read as rapidly as the investigator can identify the objects being sampled. This method allows for better comparison and interpretation of data with a minimum number of plots than the previous frequency method.

c. Nested Frequency Method (see USDI 1985, Technical Reference 4400-4, Section 4.46). Use of the nested plot design will improve the chance of selecting a proper plot size for frequency sampling. Requires slightly longer time to examine and record than the previous frequency methods.

d. Point Intercept Method. Multiple points are taken at sample locations at intervals along a tape. Numerous points are necessary to provide a desired level of sampling since each "hit" or point only records one species. Floyd and Anderson (1983) developed a point frame which has been shown to give good results for determination of foliar cover. The same frame design would be suitable for frequency determination. Properly conducted the method is objective and essentially unbiased. Points can not be resampled for comparison at a later date.

6.4 Plant Density. Density is the number of sampled objects or individuals per unit of area (Brown 1954). Density is a good, absolute quantitative measure. It is usually expressed in terms of species density per unit area after the individuals are summed for the total area sampled.

$$\text{Density} = \frac{\text{number of individuals of species A}}{\text{total unit area}}$$

Other definitions of density have been used but should be avoided because of the confusion these create. Examples of this in the range management literature includes density being referred to the ground surface area covered by foliage, crown or basal area of vegetation. Density is often express as a percentage in a relativized format.

$$\text{Relative Density} = \frac{\text{number of individuals of species A}}{\text{total number of all species}} \times 100$$

Relative density of individual species is influenced by the density of all species. Relative density values for a species can be combined with the same species relative dominance value to form an importance value index for that species within a community. Using these two relativized values the index would range from 0 to 200 with species at the upper end of the range being dominant. Tracking changes in both density and dominance as an importance value can provide a better concept of both intra- and intercommunity changes over time than only one of the analytical measures might. Density measurements as defined in the former equations have particular value in evaluating vegetative changes caused by prescribed treatments or succession. Changes in population distributions are often monitored using this analytical measure. Two types of density measurements can be collected.

(a) Rooted density. Only the individual plants rooted in the sample are counted, this is the most commonly used.

(b) Shoot density. At a predetermined height all shoots that fall within a sample area are counted.

6.41 Potential Objectives Which May Be Monitored Using Density. General resource objectives which could use plant density determination as part of a treatment monitoring program include the following categories.

1. Site preparation.

2. Timber stand improvement.

3. Vegetation conversion.

4. Insect and disease control.

5. Improve quality or increase quantity of grass.

6. Improve quality or increase quantity of forbs.

7. Improve quality or increase quantity of shrubs.

8. Improve quality or increase quantity of trees.

9. Reduce competition form undesirable plant species.

10. Maintain desired range condition.

11. Improve streambank condition.

12. Increase watershed storage capacity.

13. Reduce consumption of water by undesirable plant species.

14. Improve esthetics.

15. Improve recreational access and use.

6.42 Advantages and Disadvantages of Density Determination. Density is one of the easiest analytical concepts for investigators to understand, the simple counting of individuals. The measurements are also considered one of the more difficult to implement. Four principal difficulties arise when using density as an analytical measure.

a. Plot size. The plot size should be based on the size and spacing of the individuals to be counted. It is impractical to count numerous individuals in large plots unless they are subdivided into smaller units. Density measures for large woody vegetation with greater spacing between individuals are usually collected in large plots.

b. Plot shape and location. Plot shape will influence the "edge effect" and the surface area of the sampling plane. The greater the amount of edge the more frequent will be the sampled object that lies on the edge. Objects on the edge of a plot require a subjective decision of whether the object is in-or-out of the plot. A circular plot shape has the least amount of edge. Circles when placed on slopes greater than 20% will need to be corrected for horizontal surface area. Horizontal surface area in a circular plot increases with increasing slope. Rectangular plots placed perpendicular to the slope minimizes the influence of slope on the plot surface area, but have a greater edge effect than circular plots. Square plots have the greatest amount of edge and are intermediate to the three shapes in terms of the influence of slope on surface area. To great of an elongated area rectangular plot increases in edge effect with results similar to small square plots (Greig-Smith 1964). Each shape is a compromise of the ideal situation, circles are best on level sites where the amount of edge is critical, rectangles are preferred on sites with greater than 20% slope. Density measures for large woody vegetation are frequently collected in large

circular plots because these are easier to establish than large square or rectangular plots with 90° corners.

c. Plant growth patterns. Single stemmed individuals usually do not present a problem, multistemmed growth forms are often difficult to define what constitutes an individual. Arbitrary limits must be predetermined on what above ground parts will be counted as an individual. These limits may vary between various vegetative strata and the size of individual species.

d. Time. Counting individuals can become a time consuming and tedious task, especially for very dense populations. If descriptive purposes are the reason for using an analytical measurement then a close look needs to be made for choosing density as that measurement. Density techniques generally take longer and may provide no more useful information than the less time consuming abundance scales.

6.43 Relationship to Other Analytical Measures. If the sampled species populations are known to be random, then frequency can be determined from the data collected. The following equations express this relationship.

$$\text{Density} = -\log_e (1 - F/100)$$

$$\text{Frequency} = 100 (1 - e^{-D})$$

Frequency can be calculated from the sample data as well since each species within a plot is recorded. Mean area per species is also the reciprocal of density and with a known random distribution the mean area per species can be calculated (Curtis and McIntosh 1950).

6.44 Comparison of Different Methodologies for Obtaining Density.

a. Quadrat Density Method. This method is used mostly when determining herbaceous densities. Transect and plot establishment requires time, especially if permanent plots are necessary for repeated observations. Plots used with this method can be established in the same manner as the Quadrat Frequency Method (see USDI 1985, TR 4400-4, Section 4.45). Usually it is desirable to use plots which have been subdivided into equal or known proportions for ease of keeping track of counts involving dense individuals.

b. Belt Transect Method. This method is a modification of the quadrat method and involves a larger plot design in the shape of a belt, or an elongated rectangle. This method is usually used to evaluate larger species such as shrubs or trees. The belt transect uses a transect as a cross section of an area to be sampled. A predetermined area is sampled and delineated by a set distance from the line transect which forms one side of the belt. Individuals within the belt are counted. Belts can be established, and observations made on either side, or alternate on both sides of the transect line. Sample area must be sufficient to provide an adequate estimate to characterize the individual population. Other measurements such as abundance and frequency, or physical attributes such as height or stem diameter can be

easily collected at the same time to supplement the density measurement.

6.5 Plant Dominance. Dominance is an important analytical factor which is often related to species importance, a measure of a species biological activity and resource utilization. Dominance is usually expressed as an analytical measure of a physical attribute or combination of attributes; such as basal area or biomass. Species dominance in a study area is often rated as a percentage in relation to the other species present and termed relative dominance.

$$\text{Relative Dominance} = \frac{\text{dominance factor of species A}}{\text{dominance factors of all species}} \times 100$$

6.51 Potential Objectives Which May Be Monitored Using Dominance. General resource objectives which could use plant dominance as part of a treatment monitoring program includes the following categories.

1. Timber stand improvement.
2. Vegetation conversion.
3. Improve quality or increase quantity of grass.
4. Improve quality or increase quantity of forbs.
5. Improve quality or increase quantity of shrubs.
6. Improve quality or increase quantity of trees.
7. Reduce competition from undesirable plant species.
8. Maintain desired range condition.
9. Increase utilization by grazing/browsing animals.
10. Create openings for travel, dusting, feeding or use.
11. Increase edge effect.
12. Improve streambank condition.
13. Increase watershed storage capacity.
14. Reduce consumption of water by undesirable plant species.

6.52 Physical Factors Measured for Obtaining Dominance.

a. Basal Area/Stem Cover. This method of estimating dominance has become the standard in ecological studies of North American forested areas (Curtis 1959). Basal area should correlate with other physical features such as tree biomass, volume and height. Data is usually collected from plots (1/300th of an acre is a commonly used tree plot size) and occasionally from belt transects.

b. Height. In forestry tree height is used as the principal measure of dominance. This parameter is easily obtained assuming the investigator has a clear line-of-sight.

c. Biomass. The measure of biomass as an indicator of dominance is generally restricted to shrub/grass and grassland communities. It is used as an indicator of annual yield of herbaceous above ground biomass. Herbaceous weight, or biomass is generally agreed to be one of the best quantitative measures of herbaceous plant response (Reppert and others 1963). This measure is susceptible to multiple influences such as climate and previous grazing history as well as the prescribed treatment being evaluated. These additional factors must be taken into account when the data is interpreted. Several methods have been devised to provide direct herbaceous biomass estimates. Variations of these basic methods are commonly used in several BLM herbaceous utilization study methods (see USDI 1984, TR 4400-3, Sections 5.21 - 5.23).

1. Weight from Clipped Plots Method. This method employs the destructive harvesting of herbage from all samples. Clippings are collected, dried and weighted with no estimations. Samples can be tallied by species, plot or study area. Little or no training or expertise is required for the method though it can become tedious. Because the method does not use estimations of biomass the technique may be considered more time consuming than other methodologies. Because of the time factor, data from fewer samples may be collected which can pose a problem if considerable between sample variability exists.

2. Weight/Estimate Method. No plant material is harvested with this method and accuracy is dependent upon the abilities of the investigator to correctly estimate the weight. Because of the time saved by this method a greater number of samples can be estimated. Considerable training, and time, is required in developing the ability to estimate observed biomass. This training can only be acquired from actual clipping and weighting. The method can not be accurately applied by inexperienced personnel. Even with an experienced investigator accuracy can fluctuate depending on the level of mental fatigue. Additional error can be induced by different investigators converting green herbage into dried weights. These problems can be minimized by periodic clipping and checking of plots and sample estimates.

3. Plot Weight/Weight Estimate Double Sampling Method. This method utilizes the speed of visual weight/estimate method and the control and accuracy of the clipped plot method. The relationship between the estimated and actual weights on the double sampled plots is used to correct the plots where only estimates were made. This method can include the error potential listed with the two previous techniques.

4. Actual Plant or Shoot Weight Method. This method harvests a single plant unit or plant shoot which is dried and weighted.

Herbage per unit area is obtained by multiplying the single weight by the individual species density. This method can be repeated for any number of species. Considerable variance in individual plant weights can induce error into the biomass estimate.

Indirect methods of estimating biomass use mathematical relationships between various physical factors and biomass. The relationships generally are expressed as allometric equations and are usually species or generic specific. The equations are developed from a physical factor, or series of factors which have been shown to be reasonably accurate in expressing the estimated biomass. Equations are usually developed for a particular portion of a plants range and it would be a serious error to assume the relationships are valid over the entire range. Better relations are usually expressed for shrubs and trees which tend to display a long-term stability in annual accumulated yield. Relationships for herbaceous phytomass can frequently be inconsistent due to influences from climate and various prescribed treatments. Indirect biomass estimates have received considerable use in evaluating wildlife habitat, forest fuel (Smith and Brand 1983) and rangeland fuel conditions. Several of the techniques have been adapted for BLM biomass utilization studies (see USDI 1984, TR 4400-3, Sections 5.24 - 5.32). These indirect methods are generally considered to be less time consuming than the direct biomass estimates once the physical relationship has been established. Biomass computation can also be considerably faster since the equations are easily established in computer programs which accept the physical data (Bushey and others 1986).

5. Height Method. Plant height has been indicated as having a relationship to biomass (Reppert and others 1962). Visual estimates of height should be avoided because of introducing error. A series of actual height measurements should be taken by the investigator.

6. Cover Method. Cover measurements may be based on certain plant parts (base, leaf) or on the foliar cover for the entire plant. Basal coverage may show a good relationship to biomass for bunchgrasses (Reppert and others 1963). Humphrey (1985) found reasonably good relationship between foliar cover and biomass for grasses and shrubs in a sagebrush/grass ecosystem. Foliar coverage has shown varied success in predicting forest understory shrub and herbaceous biomass (Ohmann and others 1981). Cover estimates can be obtained either by ocular estimates or calculated from actual measurements. Ocular estimates often introduce personal error and bias and are not always consistent between observers.

7. Height and Cover Method. The combination of height and cover produces a rough approximation of volume. Volume has been shown to be related to biomass in range grasses (Crafts 1938, Evans and Jones 1958, Reppert and others 1962). The use of height and cover measurements have also been used to determine shrub biomass (Brown and Marsden 1976, Brown 1982, Frandsen

1983, Murray and Jacobson 1982). This method will incorporate the potential areas of error from both the cover method and the height method.

8. Diameter Method. Stem diameter has frequently been used as a factor in the estimation of shrub (Brown 1976, Brown 1982) and tree biomass (Brown 1978, Raile and Jakes 1982).

When using any one of the appropriate methods to determine herbaceous biomass it may be necessary to protect some portion of the area to be sampled from other management activities which would have the potential to influence the untreated results. Grazing or clipping will have an effect on growth and yield and it will be necessary to establish new plots each sample season which have not been influenced by these factors. Temporary or permanent exclosures can be installed to restrict grazing, and sample plots can alternate between differing locations adjacent to a transect to avoid previously clipped plots. These precautions will aid in providing a controlled experimental environment.

d. Cover. The use of coverage as an estimate of dominance has had many applications. Simply defined, cover is the proportion of ground covered by vegetation or other objects being evaluated. In forestry the terms crown cover, forest cover and ground cover are used. Range studies usually use shrub cover, and foliar or basal cover. Basal coverage is a vertical projection of the root crown area onto the ground surface while foliar cover is the projection of the entire aerial portion of the plant. Measures of coverage have been used to measure both unplanned and prescribed treatments to vegetation. The type of cover value measured needs to be considered in both measuring and evaluating the degree of change exhibited by the structure and composition of the vegetation from a treatment. Foliar cover of herbaceous plants is more sensitive to changes caused by season, climate and grazing than is basal cover. Basal cover is rarely estimated for shrubs because it inadequately reflects the importance of these species. Basal cover is also not usually estimated for annuals, single-stemmed plants and rhizomatous species because of the smaller unit basal area. Basal cover for bunchgrass species needs to be defined as basal coverage by live tissue to more accurately reflect changes induced by a treatment. Basal coverage is a good method for recording long-term vegetational changes and is not as greatly affected by seasonal fluctuations or by other factors such as weather and grazing. In some instances cover has been used as a measure of protective quality, estimating herbage yield and development of composition lists. Coverage values may be either directly measured or estimated, both techniques are used by the BLM in trend studies (see USDI 1985, TR 4400-4, Sections 4.41, 4.43, 4.47).

1. Ocular Estimate Method. Visual foliar coverage estimates are obtained from a series of plots or from photographs with defined boundaries acting as a plot or delineator of specific area. The Daubenmire Cover Scale (see Quantity Ranking,

Section 6.22) is frequently used in western North America to group coverage estimates into classes. Ocular estimates are a rapid, low intensity technique that can be replicated if permanent plots are established. However, concepts of cover classification are arbitrarily defined and considerable error can be induced by different investigators. Careful training and the use of plot frames reduces error.

2. Plot Charting Method. Plots of vegetation foliar cover are mapped on a grid pattern from which coverage is later determined. This technique can be accomplished visually in the field or from a photograph taken from a position above a plot or site of known area. This technique has been successfully used to monitor successional change and vegetal longevity on a small scale. Plot charting is impractical and time consuming for numerous samples or large areas unless the measuring can be either automated or coverage estimates limited to a few large species. Personal bias with this method can be great and not consistent from site to site or between investigators. The cover of plants after being shown diagrammatically still needs to be measured. The method is very difficult to use where plants have overlapping canopies.

3. Line Intercept Method. Obtaining efficient horizontal, linear measurements of plant intercepts has often been used to describe species coverage. The method can sometimes be time consuming when accurate measurements of herbaceous basal cover is needed; especially if rhizomatous grasses, or numerous single-stemmed small plants are involved. Determining bunchgrass, shrub and tree foliar cover can be relatively rapid depending upon the length of transect needed for a sample. Dense, tall shrubs can be a disadvantage in establishing exact transects. Multiple lines are usually used to obtain coverage measurements so the lines do not cross vegetation or soil types. Line length varies but usually exceeds 25 feet in length. Daubenmire (1959) found that 1,148 feet (350 meters) of line intercept transect was comparable to coverage measurements obtained from 40 to 50 1/10 m^2 plots for shrubs in western steppe. But line intercept is preferred where levels of high precision and confidence are required (Hanley 1978). For consistent results between different investigators it is better to sample from one canopy edge to the opposite edge. Canopy gaps greater than eight inches are subtracted. Other measurements which can be obtained from line intercept data include composition, abundance, and average diameter of individual species. Intercept data can not be used or interpreted for any measure requiring an area measurement, since theoretically a line is a series of points with no dimension. Line intercept is generally objective and relatively accurate. It can be randomized and replicated to obtain desired precision and may be collected in either a permanent or temporary manner. It is particularly suited for measuring low shrubs and herbaceous vegetation. Training of investigators may be necessary to eliminate subjective decisions as to size of canopy gaps to be eliminated during sampling.

4. Point Intercept Method. Goodall (1952) reviewed the point intercept method and found that the technique provided reliable data for vegetational analysis. Point intercept sampling is based on the assumption that a point has no dimension. Actual sampling involves a pin or needle which will vary in thickness. The thicker the needle the greater will be the over estimation of cover (Goodall 1952). Usually multiple points are taken at sample locations at intervals along a tape. Floyd and Anderson (1983) developed a point frame which has been shown to give good results for foliar cover in sagebrush-grass vegetation. Determination of basal coverage by the point intercept method is more labor intensive. Point sampling permits quantitative determination of cover and species composition in terms of cover. Properly conducted the method is objective and essentially unbiased. Individual points are temporary because they can not be accurately replicated. This method is particularly suitable for short, compact, and sod-forming vegetation types. It is not suitable for tall shrubs and trees. Frequently numerous points are necessary to provide a desired level of sampling precision.

e. Volume. Height and cover measurements produce a rough approximation of volume which has been shown to be related to biomass in range grasses and shrubs (see Plant Dominance, Section 6.2). Volume has been used as a direct measure of dominance and successional development following treatment for herbaceous and small shrub/tree strata (Stickney 1980).

6.6 Plant Diversity. Maintaining or increasing species diversity is often a goal on land units following a management treatment. Species diversity is most often equated with Whittaker's (1972) definition of alpha diversity which refers to the number of species in a given community (richness) and the manner in which the importance of those species are distributed (evenness). Species importance is a measure of a species biological activity and resource utilization, and is usually derived from estimates of density or dominance. The best measure of alpha diversity would be a combination of species richness and evenness. Peet (1974) refers to this as the "dual concept measure". Numerous indices have been developed, all are not applicable for evaluating treated sites. A recent comparison of several techniques for measuring diversity was compiled by Chambers (1983). Since the basis for comparison is the prior untreated site, an index must be suitable for direct comparison between the pre- and post-treatment communities. The appropriate index must compare the alpha diversity of the two communities and result in an index of similarity.

6.61 Potential Objectives Which May Be Monitored Using Similarity Indices. General resource objectives which could use diversity indices as part of a treatment monitoring program include the following categories.

1. Vegetation conversion.

2. Insect and disease control.

3. Maintain desired range condition.

4. Improve esthetics.

5. Restore and maintain natural role of fire.

6.62 Similarity Indices. The following similarity indices allow comparison of two communities and are sensitive to changes in species composition and importance. They are easy to compute and understand with the index values ranging from 0 to 1 with 1 being complete similarity. Modifications to the Sorensen's Index emphasizes strictly quantitative properties. Sorensen's Index measures the actual species in common from the two communities against the theoretically possible species in common and gives greater weight than Jaccard's Communitiy Coefficient to the species that are in common within the two communities than to those species that are unique to either (Mueller-Dombois and Ellenberg 1974). Jaccard placed a large emphasis on the comparison of the number of common and different species and the differences in importance values between individual species (Chambers 1983). Spatz's modification of the Jaccard Coefficient emphasizes the quantitative and qualitative properties of the two sampled communities.

a. Motyka's and others (1950) version of the Sorensen's Similarity Index (Sorensen 1948) .

$$IS_m = \frac{2\ IV_s}{IV_a + IV_b} \times 100$$

* Symbol interpretation for all equations are listed below.

b. Bray and Curtis (1957) version of the Sorensen's Similarity Index (Sorensen 1948).

$$IS_{bc} = \frac{2\ IV_s}{200} \times 100 \quad \text{or} \quad IS_{bc} = \frac{IV_s}{100}$$

c. Spatz's (1970) modification of Jaccard's Community Coefficient (Jaccard 1912).

$$IS_s = \frac{\sum_{i=1}\left(\frac{IV_{v1}}{IV_{L1}} \cdots \frac{IV_{vi}}{IV_{Li}}\right)}{n} \times \frac{(IV_{c1})}{IV_a + IV_b + IV_c} \times 100$$

d. Ellenberg's (1956) modification of Jaccard's Community Coefficient (Jaccard 1912).

$$IS_e = \frac{(IV_c / 2)}{IV_a + IV_b + (IV_c / 2)} \times 100$$

IV_a = the sum of the importance values for all species or life forms in community A.

IV_b = the sum of the importance values for all species or life forms in community B.

IV_c = the sum of the importance values of all species or life forms common to both communities.

IV_s = the sum of the smaller of the two importance values for the species or life forms common to both communities.

IV_v = the smaller importance values of the species or life form common to both communities.

IV_L = the larger importance values of the species or life form common to both communities.

n = total number of species or life forms in both communities.

6.7 Photographs and Nonphotographic Imagery. Periodically repeated photographs or nonphotographic imagery used for comparison purposes of the same land-unit or plot can provide visual evidence of vegetation and site successional changes over time. Photographs and nonphotographic imagery can be a low intensity, qualitative or semi-quantitative monitoring method that provides general data concerning the land-unit which may reflect important vegetational changes. If changes are apparent more intensive monitoring efforts may be needed. USDI Technical Reference 4400-9 (1986) provides a selected bibliography of aerial and satellite remote sensing capabilities.

6.71 Potential Objectives Which May Be Monitored Using Photographs or Nonphotographic Imagery. General resource objectives which could use photography and/or nonphotographic imagery as part of a treatment monitoring program include the following categories.

1. Vegetation conversion.
2. Woodland/timber product debris removal.
3. Hazard reduction.
4. Insect and disease control.
5. Reduce competition from undesirable plant species.
6. Create openings for travel, dusting, feeding or use.
7. Increase edge effect.
8. Maintain fuel breaks.
9. Improve esthetics.
10. Improve recreational access and use.
11. Improve boundary lines around previously disturbed units.

6.72 Advantages and Disadvantages of Photographs and Nonphotographic Imagery. Photographs have historically provided us with a visual record of vegetation and site or landscape conditions from which a limited amount of cover and composition estimates could be derived. Satellites and other orbiting platforms have expanded the scale and the range of imagery opportunities by allowing us to acquire high resolution, multispectral data with repetitively over large regions of the globe.

a. Photographs. Photographs are easily composed and taken, and with proper guidelines the scenes may be easily retaken during later seasons or years for comparison purposes. Because of the speed with which a photograph can be taken, and depending on the level of photo analysis this method is very economical. Photographs, and especially aerial and satellite photographs, are frequently used to classify and map vegetation since they can provide imagery of cover types. Underlying forest vegetation can sometimes be interpreted through canopy openings, or inferred from the overstory. Different types of film have been shown to exhibit varying characteristics of the dominant vegetation (Driscoll 1971). Selection of the film type should be done in consultation with a professional photographer making sure they understand the type of information the investigator is seeking. If small features, such as seedlings, within a photograph are of importance they may need to be marked or distinguished in some manner before the photo has been taken. Photographs, especially of photo plots, sample only a very limited area and should be used carefully for extrapolating information to larger land units. It is very important that pretreatment baseline photographs

be acquired to compare with later changes. The baseline photography should be from a time period exhibiting the vegetation during a "normal" season. Unusual weather conditions, such as drought, can have a large impact on vegetation and may affect interpretation of later photographic comparisons. Compatibility of scale between comparison photographs is preferred. Widely varying scales may require specialized equipment to view and compare the images.

b. Nonphotographic Imagery. The use of sensors to monitor the earths surface by measuring reflected wavelengths from the nonvisible range has provided additional means to acquire vegetation data in a remote manner with a minimum of site visitation. Many of the advantages and disadvantages from photography are also applicable to nonphotographic imagery. Most nonphotographic imagery is acquired from an orbiting platform such as a satellite. Satellite data must be acquired by the user from an earth receiving station facility and processed either by NASA or a commercial company.

6.73 Comparison of Different Methodologies for Obtaining Photographs and Nonphotographic Imagery.

a. Close-up Photographs. This particular method (see USDI 1985, TR 4400-4, Section 3.42) generally photographs permanent plots established at the beginning of a study. Photo plots provide an excellent, low-intensity method of providing a historical record of plant succession on a small area. More detailed information such as estimates of cover, vigor, reproduction and erosion condition can be classified and mapped using the Plot Charting Method (see Plot Charting Method, Section 6.52.d.2) from the photographic record. Obtaining detailed information from photographs can be very time consuming and subject to considerable personal bias. In vegetation with overlapping canopies it may be difficult to obtain the desired information.

b. General View Photographs. Landscape photographs present a broad high oblique view of the study site (see USDI 1985, TR 4400-4, Section 3.43). They are especially useful in documenting large scale successional changes in a qualitative manner (Gruel 1980a, Gruel 1980b, Gruel and others 1982). These photos usually provide an important supplement to quantitative data and are frequently used in aiding plot and transect relocation. Gruel and others (1986) provide a method combining general view photography, quantitative and qualitative vegetation sampling, and surface biomass inventories.

c. Aerial Photographs. The application of aerial photograph interpretation to certain monitoring situations can provide a large amount of useful information from a low-intensity, relatively inexpensive method. Low altitude aerial photography differs from general view photography in two important aspects; the area viewed is usually larger with the scale adjusted by varying altitude, and the photographs are usually taken from a vertical or low oblique view of the subject. This method is particular useful in evaluating in a qualitative or semi-quantitative manner vegetation changes following large scale treatments or natural disturbances. Object heights can be determined on aerial photographs by measuring either stereoscopic

parallax or shadow lengths. Crown diameters can usually be derived as a distance measure, which can then in the case of a forested land-unit be used to estimate tree stem diameter, tree volume and stand size-classes. Tree crown closure can also be estimated ocularly or with the aid of printed density scales (Avery 1966). Oblique photographs are more difficult to obtain accurate measurements from than vertically taken photographs because of the changing scale with distance. Accuracy is very dependent on the skill of the interpreter, and usually greater accuracy is possible from flat terrain.

d. Nonphotographic Imagery. Remote sensing in the nonvisible wavelengths offers a wide range of monitoring possibilities on landscapes of varying scale. In addition to the classification of vegetation, other imagery uses have included analysis of biomass/fuels, soil-soil moisture-vegetation interactions, insect/disease detection and evaluation, air pollution impacts and the monitoring of disturbance from large scale events. The type of imagery, scale and availability is dependent upon the remote sensing platform used. Spatial resolution of the land surface also varies by satellite and type of sensor. The French SPOT satellite can provide a 10 or 20 meter (both High Resolution Visible, HRV) resolution and NASA's LANDSAT 5 has a 30 meter (Thematic Mapping, TM) or 80 meter (Multispectral Scanner, MSS) capacity (Plevin 1985). Satellite data availability can be affected by either orbit or weather conditions.

6.8 Plant Mortality/Survival. Following a prescribed treatment it is frequently necessary to assess the mortality of key species. This form of monitoring is usually followed for several years after the treatment.

6.81 Potential Objectives Which May Be Monitored When Evaluating Plant Mortality/Survival. General resource objectives which could use plant mortality/survival evaluation as part of a treatment monitoring program include the following categories.

1. Timber stand improvement.
2. Vegetation conversion.
3. Reduce competition from undesirable plant species.
4. Maintain desired range condition.
5. Improve streambank condition.
6. Increase watershed storage capacity.
7. Reduce consumption of water by undesirable plant species.
8. Improve esthetics.

6.82 Advantages and Disadvantages of Evaluating Plant Mortality/Survival. Usually only a limited number of individuals can be efficiently monitored in conjunction with other vegetation data collection. As a result, the limited sample is only an inferred

estimate of the mortality/survival of the entire species population. If individual plants are observed over an extented period of time it is possible for the investigator to assess plant vigor and note if observed mortality is treatment induced or due to other natural causes. this differentiation of mortality cause may be important if the treatment is new or experiment. Following a treatment some species may resprout but then die several years after because of treatment induced damage and low vigor.

6.83 Comparison of Different Methodologies for Obtaining Plant Mortality/Survival Data.

a. Marked Plant Method. This method efficiently accomplishes mortality/survival data collection by establishing monitoring on known locations of key species (Bunting and others 1987). The location of these individual plants can then be mapped in reference to a witness marker. At least 20 individuals per species should be located and marked. These plants should be assessed for mortality and vigor for several years following treatment. The investigator may consider it advantageous to collect photographs of each plant during the study. If mortality is caused by some observable factor, that cause should be noted especially if the mortality is not caused by the prescribed treatment. It is important to distinguish between natural and treatment induced mortality. Due to the small sample size it is difficult to apply this method except in a qualitative manner.

b. Frequency Method. Comparison of frequency measurements (see Plant Frequency, Section 6.3) from permanent plots can give a poor, but quick indication of mortality/survival of prominent species within those plots. This method will only give a very general population trend since individuals are not tracked. The frequency method does not take into account the recruitment of new individuals into new plots, nor the mortality of all individuals except one (only one individual needs to be alive per plot to be recorded). Assessment of vigor is difficult with this method unless specific plants are marked for repeated observations, otherwise only an assessment of the population as a whole may be made.

c. Density Method. Periodic resampling of permanent plots from which density data has been obtained can provide a good indication of plant mortality/survival (see Plant Density, Section 6.4), especially for shrub or tree data collected by the belt transect method. Seedling recruitment, if desired, can be monitored at the same time. Individual plants are not tracked with this method unless specifically marked making it necessary to develop general conclusions on species vigor and cause of mortality.

6.9 Surface Biomass Determination.

Inventories of total vegetational above ground biomass have been primarily developed for fire management purposes (fuel). These complete above ground biomass surveys have also been used to monitor community biomass changes overtime after management activities or to provide an indication of an area needing biomass manipulation (Gruel and others 1986). Surface biomass inventories utilize biomass methods previously

discussed (see Biomass, Section 6.52.c). However, the general purpose for the surface biomass inventory is different and deserves separate meantion. Determination of species or lifeform dominance is not a factor. The investigator is evaluating vegetational surface biomass and its various components as it effects other resource values and site management potential. If dominance is expressed it is usually as a lifeform group or by particle size.

6.91 Potential Objectives Which May Be Monitored Using Surface Biomass Inventories. General resource objectives which could use a surface biomass inventory as part of a monitoring program include the following categories.

1. Woodland/timber product debris removal.

2. Hazard reduction.

3. Improve streambank condition.

4. Maintain fuel breaks.

5. Restore and maintain natural role of fire.

6.92 Comparison of Different Methodologies For Obtaining Surface Biomass Inventories.

a. Brown's Surface Fuel Inventory. Brown and others (1982) devised an inventory system which for the North American Interior West, and specifically for the Northern Rocky Mountains. The inventory was initially developed to provide estimates of fuel loading as input to the development of potential fire behavior prediction. The methodology emphasizes down and dead forest fuels , but the estimates of above ground biomass of conifer litter, herbaceous vegetation, shrubs and small conifers may have other uses as well. The inventory has certain advantages over other methods such as;

1. little training is required,

2. does not require checking weight estimates against actual weights,

3. estimates are not affected by changes in light or moisture content as can happen with the weight-estimate technique,

4. quantities of vegetation can be rated on a relative basis easily.

Limitations of the method include;

1. the set of plots must all be readily visible to the investigator to permit accurate comparisons,

2. clipping and bagging on one plot is necessary out of every set of four plots,

3. accuracy of the method has received little study outside of the region it was designed for,

4. the method is probably not as accurate as weight-estimate method used by trained and experienced observers.

It is suggested that at least 15 to 20 sample points be established and for units over 50 acres containing a higher diversity more sample points should be used.

b. DEBMOD. Puckett and others (1979) developed a computerized procedure for processing standardized USDA Forest Service forest stand exam data to predict the resultant debris from planned harvested trees. The predicted tree debris is added to the debris previously on-site. Average debris depth is estimated over a 5 year post harvest period. This method allows managers to examine before treatment the possible effects of different forest management techniques that may create debris or residue. The DEBMOD program was designed to be used in conjunction with another computer program called HAZARD which predicts fire behavior from the modeled fuelbed. DEBMOD was designed to be used in the planning process, however it may also serve as a portion of a biomass inventory monitoring program. Use of the DEBMOD program is restricted to North American conifers. Herbaceous and shrub components of the ecosystem are not modeled.

c. General View Photographs. General view photographs (see Photographs, Section 6.7) can be taken of areas on which surface biomass inventories have been conducted. These photographs and their accompanying data can be compiled into a photo guide for providing biomass/fuel estimates on similar sites (Fischer 1981a, 1981b). This method is used on pretreatment sites and would be applicable to posttreatment sites if a suitable manual was developed. These manuals need to be compiled for similar biomass/fuel types from a limited geographic region. Experience is needed to evaluate the suitability of a manual from a similar vegetation type but different region of the country. The precision level of different experienced investigators estimating biomass/fuel from photographs is unknown. Cost of application can be low to intermediate depending on the number of different biomass/fuel situations and the amount of use the photo guide might receive. of areas on which surface fuel inventories have been conducted.

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TREND STUDY DATA
COMMUNITY STRUCTURE ANALYSIS METHOD - FOLIAR COVER DATA

PAGE ____ OF ____

STUDY NUMBER	DATE	EXAMINER	ALLOTMENT NAME & NUMBER	PASTURE

COVER CATEGORY AND PLANT SPECIES	COVER CLASS 1 1-5 % (2.5) DOT COUNT	#	**COVER CLASS 2 5-25 % (15) DOT COUNT**	#	COVER CLASS 3 25-50 % (37.5) DOT COUNT	#	**COVER CLASS 4 50-75 % (62.5) DOT COUNT**	#	COVER CLASS 5 75-95 % (85) DOT COUNT	#	**COVER CLASS 6 95-100% (97.5) DOT COUNT**	#	PERCENT COVER
LITTER													
ROCK ≥ 1/2 INCH													

Illustration 1. Folia Cover Data Sheet.

$$\text{Percent Cover by Species} = \sum \frac{[(\text{No. in})(\text{Midpoint})\ (\text{Class 1})(\text{Class 1}) + (\text{No. in})(\text{Midpoint})\ (\text{Class 2})(\text{Class 2}) + \ldots + (\text{No. in})(\text{Midpoint})\ (\text{Class 6})(\text{Class 6})]}{100}$$

NOTES (USE OTHER SIDE OR ANOTHER PAGE)

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TREND STUDY DATA
DAUBENMIRE METHOD - SIX COVER CLASSES

PAGE ____ OF ____

STUDY NUMBER	DATE	EXAMINER	ALLOTMENT NAME & NUMBER	PASTURE

PLANT SPECIES	COVER CLASS 1 1-5 % (2.5) DOT COUNT	#	COVER CLASS 2 5-25 % (15) DOT COUNT	#	COVER CLASS 3 25-50 % (37.5) DOT COUNT	#	COVER CLASS 4 50-75 % (62.5) DOT COUNT	#	COVER CLASS 5 75-95 % (85) DOT COUNT	#	COVER CLASS 6 95-100% (97.5) DOT COUNT	#	FREQ-UENCY (%)	CANOPY COVER-AGE (%)	SPECIES COMP. (%)

CALCULATION INSTRUCTIONS

$$\text{Frequency (\%)} = \frac{\text{Number of occurrences of a plant species}}{\text{Number of frames observed along the transect}} \times 100$$

$$\text{Canopy coverage (\%)} = \frac{\sum\left[\begin{array}{l}(\text{No. in Class 1})(\text{Midpoint Class 1}) + (\text{No. in Class 2})(\text{Midpoint Class 2}) + \ldots + \\ (\text{No. in Class 6})(\text{Midpoint Class 6})\end{array}\right]}{\text{Number of frames observed along the transect}}$$

$$\text{Species composition (\%)} = \frac{\text{\% canopy coverage by species}}{\text{Total canopy coverage}}$$

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TREND STUDY DATA
DAUBENMIRE METHOD - TEN COVER CLASSES

PAGE ____ OF ____

STUDY NUMBER	DATE	EXAMINER	ALLOTMENT NAME & NUMBER	PASTURE

COVER CLASS	1 (2.5)	2 (8.75)	3 (18.75)	4 (31.25)	5 (43.75)	6 (56.25)	7 (68.75)	8 (81.25)	9 (91.25)	10 (97.5)		CAN	SPEC
	0-5 %	5-12.5 %	12.5-25 %	25-37.5 %	37.5-50 %	50-62.5 %	62.5-75 %	75-87.5 %	87.5-95 %	95-100 %	FREQ	COV	COMP
SPECIES	DOT CT	DOT CT	DOT CT	DOT CT	DOT CT	DOT CT	DOT CT	DOT CT	DOT CT	DOT CT	(%)	(%)	(%)

CALCULATION INSTRUCTIONS

$$\text{Frequency (\%)} = \frac{\text{Number of occurrences of a plant species}}{\text{Number of frames observed along the transect}} \times 100$$

$$\text{Canopy coverage (\%)} = \frac{\sum\left[\begin{array}{l}(\text{No. in Class 1})(\text{Midpoint Class 1}) + (\text{No. in Class 2})(\text{Midpoint Class 2}) + \ldots + \\ (\text{No. in Class 10})(\text{Midpoint Class 10})\end{array}\right]}{\text{Number of frames observed along the transect}}$$

$$\text{Species composition (\%)} = \frac{\text{\% canopy coverage by species}}{\text{Total canopy coverage}}$$

Illustration 4. Pace Frequency Method Data Sheet

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TREND STUDY DATA
PACE FREQUENCY METHOD

STUDY NUMBER	DATE	EXAMINER

ALLOTMENT NAME & NUMBER	PASTURE

COVER CATEGORY	TRANSECT 1	TRANSECT 2	TRANSECT 3	TRANSECT 4	TOTALS	COV %
BARE GROUND						
PERSIST LITTER						
NON-PER LITTER						
ROCK (≥1/2 INCH)						
LIVE VEG (BASAL)						
COVER TOTALS						100%

PLANT SPECIES	FREQUENCY				TOTALS	FREQ %

NOTES (USE OTHER SIDE OR AN PAGE)

Illustration 5. Quadrat Frequency Method Data Sheet

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TREND STUDY DATA
QUADRAT FREQUENCY METHOD

STUDY NUMBER	DATE	EXAMINER

ALLOTMENT NAME & NUMBER	PASTURE

COVER CATEGORY	TR 1	TR 2	TR 3	TR 4	TR 5	TR 6	TR 7	TR 8	TR 9	TR 10	TOTALS	COV %
BARE GROUND												
PERSIST LITTER												
NON-PER LITTER												
ROCK (≥1/2 INCH)												
LIVE VEG (BASAL)												
COVER TOTALS												100%

PLANT SPECIES	FR	FREQUENCY										TOTALS	FREQ %

NOTES (USE OTHER SIDE OR ANOTHER PAGE)

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TREND STUDY DATA
NESTED FREQUENCY METHOD - FOUR TRANSECTS

STUDY NUMBER	DATE	EXAMINER

FRAME SIZES	1 / 4	2 / 3	ALLOTMENT NAME & NUMBER	PASTURE

PLANT SPECIES	TRANSECT 1	TRANSECT 2	TRANSECT 3	TRANSECT 4

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TREND STUDY DATA
NESTED FREQUENCY METHOD - FOUR TRANSECT SUMMARY

STUDY NUMBER	DATE	EXAMINER

FRAME SIZES	1 / 4	2 / 3	ALLOTMENT NAME & NUMBER	PASTURE

PLANT SPECIES	TRANSECT 1	TRANSECT 2	TRANSECT 3	TRANSECT 4	TOTALS	FREQUENCY(%)

NOTES (USE OTHER SIDE OR ANOTHER PAGE)

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TREND STUDY DATA
NESTED FREQUENCY METHOD - TEN TRANSECTS

PAGE ____ OF ____

FRAME SIZES 1 / 4	2 / 3	STUDY NUMBER	DATE	EXAMINER	ALLOTMENT NAME & NUMBER	PASTURE

PLANT SPECIES	TRANS 1		TRANS 2		TRANS 3		TRANS 4		TRANS 5		TRANS 6		TRANS 7		TRANS 8		TRANS 9		TRANS 10	

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TREND STUDY DATA
NESTED FREQUENCY METHOD - TEN TRANSECT SUMMARY

PAGE ____ OF ____

FRAME SIZES	1 | 2 / 4 | 3	STUDY NUMBER	DATE	EXAMINER	ALLOTMENT NAME & NUMBER	PASTURE

PLANT SPECIES	TRANS 1	TRANS 2	TRANS 3	TRANS 4	TRANS 5	TRANS 6	TRANS 7	TRANS 8	TRANS 9	TRAN 10	TOTALS	FREQ(%)

NESTED FREQUENCY ANNUAL SUMMARY

DISTRICT _____ RESOURCE AREA _____ ALLOTMENT _____

KEY AREA NAME/NO. _____ DATA BY _____ DATE _____ NO. QUADRATS ____

NO. OF OCCURRENCES, % FREQUENCY, TOTAL HITS AND % COVER BY YEAR

SPECIES	REC. PLOT NO.	YEAR OF TRANSECT READING											
		NO. OF OCCUR.	% FREQ.	NO. OF OCCUR.	% FREQ.	NO. OF OCCUR.	% FREQ.	NO. OF OCCUR.	% FREQ.	NO. OF OCCUR.	% FREQ.	NO. OF OCCUR.	% FREQ.
GRASSES													
FORBS													
SHRUBS													
GROUND COVER SUMMARY		TOTAL HITS	% COVER	TOTAL HITS	% COVER	TOTAL HITS	% COVER	TOTAL HITS	% COVER	TOTAL HITS	% COVER	TOTAL HITS	% COVER
Non-Persist. Litter													
Bare Ground													
Persist. Litter													
Vegetation													
Cobble & Stone													
Gravel													
Cyptogams													
TOTAL													

Illustration 10. Nested Frequency Annual Summary Sheet

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TREND STUDY DATA
COMMUNITY STRUCTURE ANALYSIS METHOD - DENSITY AND FREQUENCY DATA

STUDY NUMBER	DATE	EXAMINER

ALLOTMENT NAME & NUMBER	PASTURE

	PLOT NUMBER											
PLANT SPECIES	1	2	3	4	5	6	7	8	9	10	DENSITY (TOTAL)	FREQUENCY (%)

☆GPO 578-589

Illustration 12. Weight Estimation and Vegetation Characterization Data Sheet

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SOIL–VEGETATION INVENTORY METHOD
WEIGHT ESTIMATE AND VEGETATION CHARACTERIZATION DATA

Notes:

V2

(2) INV AAAX	(3) SWA ANNN	(4) TRN NN		(1) PG NNNN

REC V2-1	LINE 01	(5) ACT A	(6) CA A	(7) MAP ID X(16)	(8) RECDR XXX	(9) DT (YYMMDD)

WEIGHT ESTIMATE DATA
PLOTS TO BE CLIPPED *(Circle)*

1 2 3 4 5 6 7 8 9 10

VEGETATION CHARACTERIZATION
PLOTS TO BE CHARACTERIZED *(Circle)*

1 2 3 4 5 6 7 8 9 10

REC V2-2

(10) PLOT SIZE *(Check One)* NNN.NN
[ ] .90 [ ] 9.60 [ ] Other — — — . — —

(11) PLOT SIZE *(Check One)*
[ ] 100th [ ] 200th

LINE NN	(12) ACT A	(13) PLT NUM NN	(14) PLNT X(5)	(14) PLNT NN	AVERAGE (15) AVAIL A	AVERAGE (16) PHNO N	AVERAGE (17) UTIL N	(18) GREEN WEIGHT IN GRAMS NNNN HGT 1 EST	HGT 1 CLIP	HGT 2 EST	HGT 3 EST	AVERAGE (19) HGT NN.NN	AVERAGE (20) DIA NN.NN	(21) AGE CL A	(22) FORM CL N	(23) NUM CHARZ NNN	(24) NOT CHARZ NNN
02																	
03																	
04																	
05																	
06																	
07																	
08																	
09																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	

(Instructions on reverse) A B C D E F I K L M N Ø P Q R S T U V W X Y Z 1 2 3 4 5 6 7 8 9 0 Form 4412–27 (April 1982)

Beneath each field heading are Alpha, Numeric, or Alphanumeric Codes, indicating the size of the field.

A – ALPHA CODE: A–Z
N – NUMERIC CODE: 0–9
X – ALPHANUMERIC CODE: Any combination of Alpha and Numeric or special (e.g., *,++) characters. For any A, N, or X Code followed by a number in parenthesis, the number indicates field size.

For Alpha and Numeric Codes, see bottom front of form.

SPECIFIC INSTRUCTIONS

Item	*Data Element*	
1	3518	**PAGE NUMBER** – Enter consecutive page numbers for all Transects *(V1, V2)* for entire inventory area *(See instruction from V1 form).*
2	3940	INVENTORY CODE – Enter Inventory Code, e.g., Worland Dist. Inventory # 1, WOR1.
3	3507	SITE WRITEUP AREA – Enter code as assigned by the field office. Code *must* be unique and in consecutive order within an inventory area, e.g., A001.
4	3508	TRANSECT NUMBER – Enter number *(01 thru 99).* If more than one transect per SWA, numbers must be consecutive and unique.
5	7350	ACTION CODE – Applies to V2–1 record. Enter "A" to add record, "C" to change existing data, or "D" to delete existing record.
6	3572	COMPARISON AREA – Enter "C" if data is from Comparison Area, otherwise, leave blank.
7	3582	MAP IDENTIFIER – Enter Aerial Photo Number, Topographic Map Name, Quad Name, etc.
8	6525	RECORDER – Enter Recorder's initials.
9	6618	DATE – Enter Date of Recordation *(YR, MO, Day).* *NOTE:* If items 5 thru 9 above have been recorded on the V1 form *(Step-point Transect Data)* they need not be filled out on this form.
10	3510	PLOT SIZE – Check the box for plot size used in the weight estimate of grasses, forbs, shrubs, and trees. If "other" box is checked, enter specific plot size. *NOTE:* That all grasses and forbs are characterized within the weight est. plot.
11	3514	PLOT SIZE – Check the box for plot size used for shrub and tree characterization.
12	7350	ACTION CODE – Applies to V2–2 record. Enter "A" to add record, "C" to change existing data, or "D" to delete existing record.
13	3512	PLOT NUMBER – Enter plot number from which weight estimate and/or characterization data is being collected.
14	2640	PLANT CODE – Enter alpha or alpha and special character(s) part of the plant code in first column and numeric part in second column for plants within plot. If plot has no vegetation, enter the word BARE in first column.
15	3830	AVAILABILITY – Enter average availability by plant species occurring in the plot. Code as follows: A – Available 100% P – Partially Available 75% H – Half Available 50% L – Limited Availability 25% U – [illegible]
16	3712	PHENOLOGY – Enter average phenology by plant species occurring in the plot. Code as follows: 1 – Begin Growth 2 – Vegetative Stage 3 – Boot Stage 4 – Peak Flowering 5 – Seed Ripe 6 – Mature 7 – Dormant 8 – Regrowth
17	3832	UTILIZATION – Enter average utilization by plant species occurring in the plot. Code as follows: 0 – 0% 1 – 01 to 20% 2 – 21 to 40% 3 – 41 to 60% 4 – 61 to 80% 5 – 81 to 100%
18	3941	GREEN WEIGHT IN GRAMS – Enter weight *(FST CLIPPED)* to the nearest gram by plant species *(NO TRACES),* for each height category *(D.E. 3523)* as follows: Ht 1 = 0–4 1/2' Ht 2 = > 4 1/2' – 7' Ht 3 = > 7' *(Enter the clipped weights for height 1 in column provided.)*
19	3504	HEIGHT – Enter the plot average height in feet and hundredths of feet for the plant species characterized.
20	3522	DIAMETER – Enter the plot average basal diameter for grasses or crown diameter for forbs, shrubs, and trees.
21	3502	AGE CLASS – Enter age class for each plant species characterized, use separate lines for each age class. Code as follows: S – Seeding Y – Young M – Mature D – Decadent O – Old *(Trees Only)* P – Pole Sapling *(Trees Only)* R – Resprout *(Shrubs Only)*
22	3503	FORM CLASS – Enter form class for each plant species characterized. Use separate lines for each form class. Code as follows: 1 – Normal and Vigorous 2 – Dying Center *(Grasses Only)* 3 – Hollow Center *(Grasses)* – Portion Dead or Dying *(Forbs, Shrubs, Trees)* 4 – Clump Edge *(Grasses Only)* 5 – Dead *(If form class 5, do not record average height, diameter, or age class.)*
23	3918	NUMBER CHARACTERIZED – Enter number of all grass and forb plants encountered within the weight estimate plot. For shrub and tree species encountered characterize a minimum of five (5) plants each.
24	3531	NUMBER NOT CHARACTERIZED – Enter the number of shrubs and trees in excess of the number characterized.

POUNDS PER ACRE AIR-DRY WEIGHT WORKSHEET

CALCULATED BY: _____

Allotment: Pasture: Key Area #: Range Site: Date:

	PLANT SPECIES	Type: G,F, T or S	Phenology Stage	Grn. wt(gms) adj. for util	Pheno. l. adj.fact.	Air-dry wt. adj. fact.	Climatic adj. fact.	Pres. Prod. lbs./acre
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
							TOTAL:	

Illustration 13. Pounds per Acre Air-Dry Weight Worksheet

Illustration 14. Plot Charting Method 3' x 3' Plot Sketch Sheet 52.

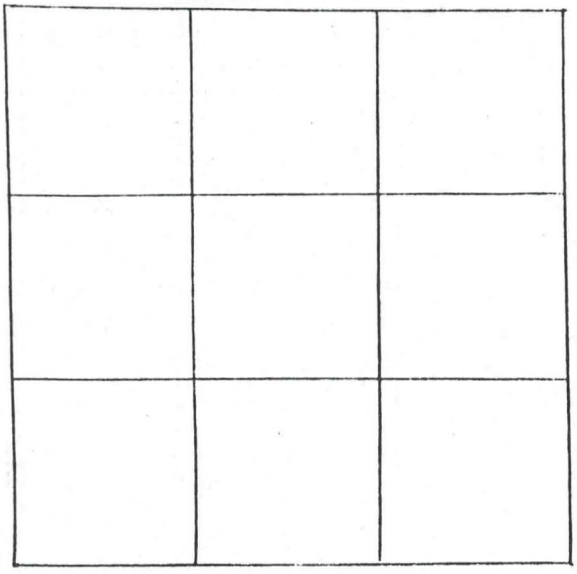
Allot. _____

Plot _____

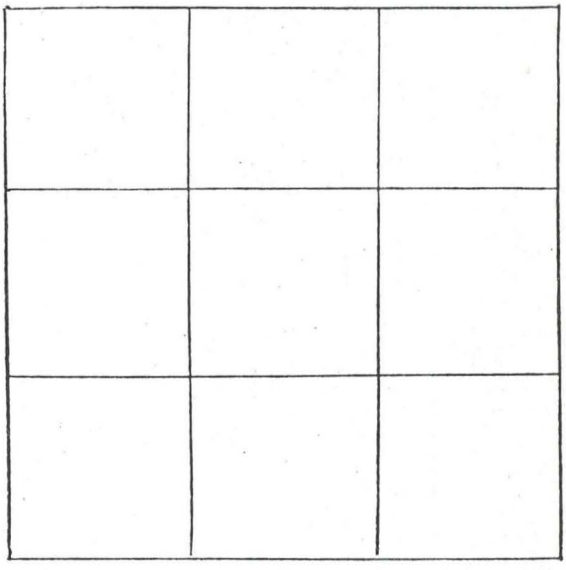
Pasture _____

SKETCH OF 3' X 3' PLOT

DATE _____



DATE _____



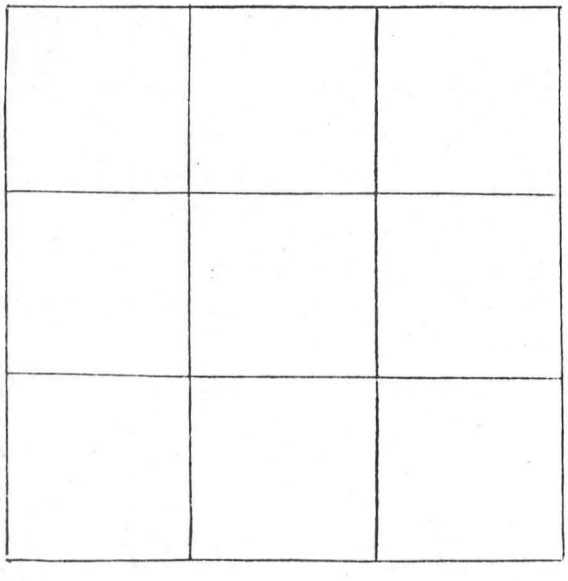
KEY _____

_____

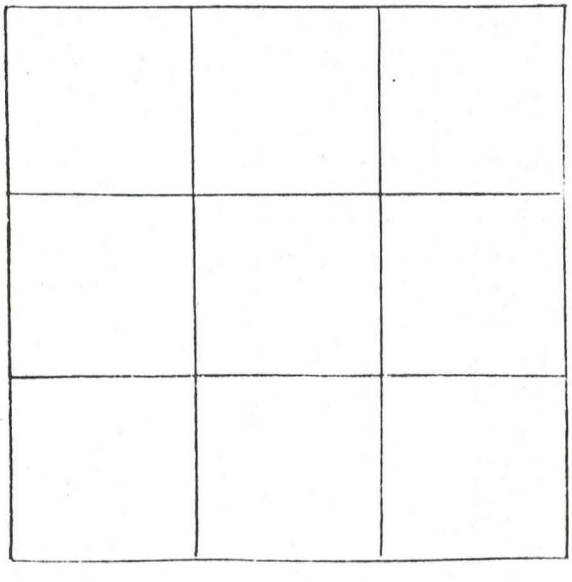
_____

_____

_____



DATE _____



DATE _____

Measurements

After the subplots and line transects have been established on the ground, begin recording general information at the top of the inventory form (fig. 4).

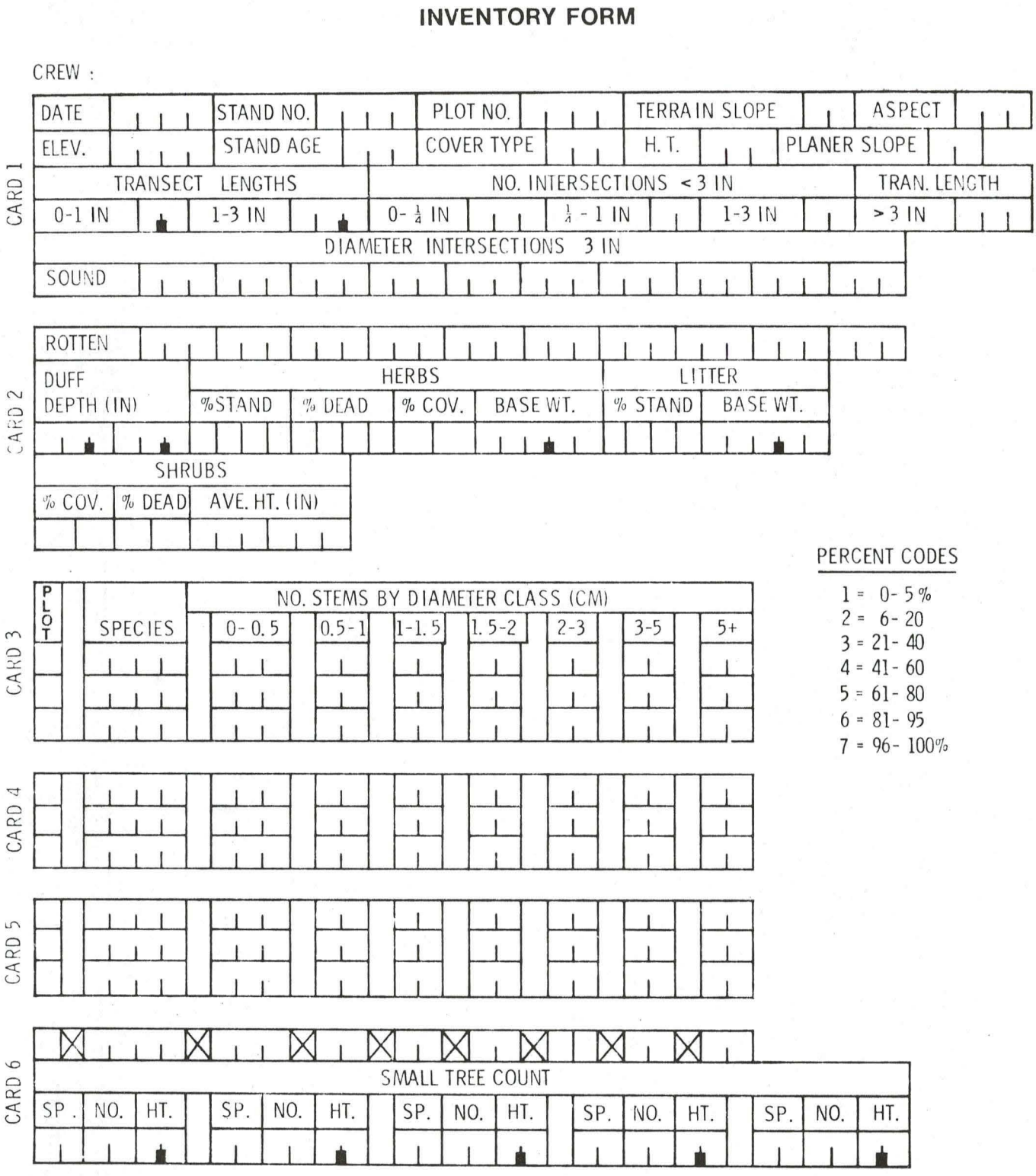


Figure 4.—Ground fuel and vegetation inventory form.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

TREND STUDY DATA
LINE INTERCEPT METHOD

PAGE ____ OF ____

STUDY NUMBER	DATE	EXAMINER	ALLOTMENT NAME & NUMBER	PASTURE

NOTES (Use other side or another page, if necessary)	GRASS SPECIES								FORB SPECIES								SHRUB SPECIES								NOTES

Allotment _____ LINE INTERCEPT STUDY Date _____

Pasture _____ Examiner _____

Plot # _____ Photo _____

_____

_____

Illustration 17. Line Intercept Method Data Sheet No. 2

Allot. _____

Past. _____

Species _____ % Cover _____ Species _____ % Cover _____ Species _____ % Cover _____

Illustration 17. (continued)